plurality of photosensitive regions each of which corresponds to a respective optical channel. The module also includes a transparent cover, in each optical channel, separated from the substrate by a spacer. The spacer is composed of a material that is non-transparent to light detectable by the image sensor. A focal length correction layer is on a surface of the transparent cover of at least one of the optical channels. Sidewalls of the transparent cover are covered by a material that is non-transparent to light emitted by or detectable by the optoelectronic device. In some implementations, the module also may include an optical filter on a surface of the transparent cover of each optical channel.

In some instances, a module may include an optics assembly on the object-side of the transparent cover. The optics assembly can include, for example, one or more lenses (e.g., a vertical stack of injection molded lenses).

Other aspects, features and advantages will be readily apparent from the following detailed description, the accompanying drawings and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows an example of an optoelectronic module.

FIGS. **2**A and **2**B are examples of optoelectronic modules according to the invention.

FIG. **3** illustrates an example of a spacer/optics structure.

FIGS. **4**A-**4**E illustrate steps in a wafer-level fabrication process for using the structure of FIG. **3** to make optoelectronic modules.

FIGS. **5**A-**5**E illustrate steps in another wafer-level fabrication process for using the structure of FIG. **3** to make optoelectronic modules.

FIGS. **6**A-**6**E illustrate steps in a further wafer-level fabrication process for using the structure of FIG. **3** to make optoelectronic modules.

FIGS. **7**A-**7**E illustrate steps in another wafer-level fabrication process for using the structure of FIG. **3** to make optoelectronic modules.

FIGS. **8**A-**8**E illustrate steps in a further wafer-level fabrication process for making optoelectronic modules.

FIGS. **9**A and **9**B illustrate steps for fabrication of proximity sensor modules that include both a light emitting element and a light detecting element in adjacent channels.

FIGS. **10**A-**10**C illustrate steps in a wafer-level process for making modules that include a vertical stack of optical elements.

FIG. **10**D illustrates an example of an image sensor module that includes a vertical stack of optical elements.

FIG. **11** illustrates yet another example of a wafer-level process for making optoelectronic modules.

FIGS. **12**A-**12**D illustrate examples of image sensor modules.

FIG. **13** illustrates an example of a module that includes a dielectric band-pass filter.

FIGS. **14**A, **14**B and **14**C illustrate steps in a further example of a wafer-level fabrication process for making optoelectronic modules.

DETAILED DESCRIPTION

The present disclosure describes various techniques for fabricating optoelectronic modules that include non-transparent material (e.g., a polymer such as epoxy with carbon black) on the exterior sidewalls of the transparent cover. An example of such a module is illustrated in FIG. **2**A, which shows a module **20** including an optoelectronic device **22** mounted on a printed circuit board (PCB) or other substrate **24**. Examples of the optoelectronic device **22** include a light emitting element (e.g a LED, an IR LED, an OLED, an IR laser or a VCSEL) or a light detecting element (e.g., a photodiode or other light sensor).

A transparent cover **26** composed, for example, of glass, sapphire or a polymer material, is separated from substrate **24** by a spacer **28**. Spacer **28** surrounds optoelectronic device **22** and serves as sidewalls for the module. Transparent cover **26** generally is transparent to wavelengths of light emitted or detectable by optoelectronic device **22**. Spacer **28** preferably is composed of a non-transparent material, such as epoxy with carbon black. Attached to one side of transparent cover **26** is an optical element such as a lens or diffuser **30**. In the illustrated example of FIG. **2**A, the optical element **30** is formed by a replication technique and, together with optoelectronic device **22**, is present in an interior area **32** of module **20**. Exterior sidewalls **34** of transparent cover **26** also are covered by a non-transparent material **36**, which may be composed of the same or a different material as is used for spacer **28**. The exterior side of substrate **24** includes one or more solder balls or other conductive contacts **38**, which can be coupled electrically to optoelectronic device **22** by way of conductive vias extending through substrate **24**.

In some cases, non-transparent material **39** extends beyond the top of transparent cover **26** near its edges. The non-transparent material **39** that extends above transparent cover **26** can serve as a baffle for the module. Depending on the implementation, the non-transparent material **36** that covers the sidewalls **34** of the transparent cover **26** can be the same as, or different from, the material of the spacer **28**. Likewise, the baffle may be composed of the same material as, or a different material from, the non-transparent material **36** that covers the sidewalls **34** of the transparent cover **26**.

In some implementations, an optical element is disposed on the exterior surface of transparent cover **26**. For example, module **40** of FIG. **2**B is similar to module **20** of FIG. **2**A, except that in FIG. **2**B there are a pair of optical elements **30**A, **30**B. The second optical element **30**B is disposed on the exterior surface of transparent cover **26**, whereas the first optical element **30**A is disposed on the interior surface of transparent cover **26**. Some implementations may include an optical element only on the exterior surface of transparent cover **26**. Other features of module **40** can be similar to the features discussed above with respect to FIG. **2**A.

The following paragraphs describe various fabrication techniques for manufacturing the foregoing optoelectronic modules and other similar modules that include a light emitting element or light detecting element and an optical element such as a lens or diffuser integrated as part of the module. Some modules can include multiple optoelectronic devices (e.g., a light emitting element and a light detecting element). In this way, proximity-type sensor modules, for example, having a light emitter and a light detector can be fabricated. In some implementations, the light emitter and light detector are separated by a spacer made of non-transparent material. In some implementations, the modules are fabricated in a wafer-scale process so that multiple modules (e.g., hundreds or even thousands) can be manufactured at that same time. The methods can include using a vacuum injection technique to form various elements on a structured substrate (i.e., a substrate that has a non-flat or non-planar surface). Forming the structured substrate can include, for example, forming openings such as trenches in a transparent wafer. The trenches then can be filled with a non-transparent material using, for example, a vacuum injection tool. Various elements (e.g., the optical elements or spacers) can be formed directly on one side or